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Sustainable development of rural energy and its appraising system in China

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Abstract

The local biomass resources have been used in rural China for quite a long time, which has a close connection with and will inevitably affect the environment. In recent years, China has experienced rapid economic growth and equally rapid increases in energy use, especially commercial energy, in rural areas. As a result, energy induced environmental degradation has also increased in rural China. This paper discusses the relationship between China's rural energy and its sustainable development. It brings forward the index system for appraising the sustainable development of rural energy (SDRE), calculates the weighing of each index with analytic hierarchy process (AHP), puts forward the quantification method and provides the basis for the research of the rural energy for sustainable development in different areas and periods. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The energy supply and consumption in rural areas is a typical problem in developing countries. China is the largest developing country in the world, with a large population in rural areas and a big difference in the social and economic development of different areas. A reasonable method of energy supply and consumption is both an important guarantee for improving economic, social and living conditions, and a significant part of the sustainable development of China. The development of the economy requires the premise of abundant energy. The local biomass resources have been used in rural areas for quite a long time, which has a close connection with and will inevitably affect the environment. Therefore, the exploitation and consumption of energy are tightly related to the development of rural areas.

Many theses have discussed the promotion on rural sustainable development by rural energy construction, especially the technology of exploiting regenerate energy [1–4]. Some researches on the countermeasure against regional sustainable development of rural energy (SDRE) dissertate the issue from different aspects [5]. China's Academy of Engineering used to set Strategic Research on Sustainable Development of Energy in Rural China as a sub-item of Strategic Research on China's Sustainable Development. Presided over by Mrs Deng, the research analyses the present situation of China's rural energy demand and supply, brings forward fairly integrated energy strategy, and establishes the base and general profile of the SDRE in China [6,7,1]. However, there hasn't been any research on the index system for appraising SDRE or the quantification method of SDRE. Only on the basis of the SDRE concept and the index system to quantitatively evaluate the SDRE, can the research be measurable and comparable.

2. The connotation of SDRE

2.1. The concept of SDRE

In a narrow sense, rural energy means the energy in rural areas. Because there is both energy consumption (mainly including the consumption by agricultural production, rural enterprises and households) and energy (mainly the renewable energy)

production in rural areas, the energy consists of imported commercial energy and local regenerate energy. In broad sense, the concept of rural energy was brought forward to refer to the situation in the rural areas in the Third World where there isn't much commercial energy, and the supply of energy depends mainly on local regenerate energy. And this strongly holds back economic development and environmental improvement. In this sense, rural energy actually refers to the energy problem in rural areas. Therefore, research on rural energy is in fact research on the technological, economic and managerial problems during the course of exploitation (or input) and consumption of energy. The purpose of the research is to acquire the biggest economic, social and ecological profits to maintain sustainable development in rural areas.

The concept of sustainable development has been widely understood and accepted. In 1987, the World Committee of Environment and Development (WCED) defined the phrase in the report *Our Common Future* as development that meets the needs of the present without compromising the ability of ability of future generations to meet their own need [8]. That is to say, we should emphasize both the satisfaction of man's various needs to reach full development and the protection of resources and ecological environment to avoid the threat against the living and development of our descendants. It pays particular attention to the ecological rationality of every activity. It appeals that the activities, which are beneficial to resources and environment, be encouraged and the reverse be abandoned. China is a developing country and development is the premise of sustainable development. China's Agenda for the 21st Century has explicitly pointed out the goal of China's sustainable development: To establish the economic and social system for sustainable development and turn out the corresponding sustainable resources and the environmental basis.

2.2. The relationship between rural energy and sustainable development in China

In the former autarkic agricultural economy in China, because there was little input of exterior energy, people depended farming and harvest on manpower and livestock, irrigation on manpower and wind power, cooking on straw and stalk and firewood. The only input of energy was kerosene for lighting, which was only several kilograms every year. With the development of rural economy and the gradual establishment of power system in rural areas in the 1960s and 1970s, some households began to use electric lighting. However, because of the instability of the power supply and peasants' low income, electricity was used very limitedly. On account of the increasing rural population, gaps emerged between the reasonable supply and the demand of local biomass energy. There was a common lack of fuel for household cooking; what's more, the environment of the district that was short of cooking fuel had already been in a serious condition; the following denudation of biomass caused soil erosion, loss of organic matter in soil and decreasing output of crops.

Since 1979, the rural economic system reform has brought about increasing output in agriculture and forestry. The increasing supply of stalk and straw and firewood, and the popularization of the firewood-saving stove and biogas digester, had basically solved the problem of fuel shortages; as part of the surplus labour force was

employed by rural industry and others went to the cities to look for jobs, the household consumption of energy decreased; the commercialization of energy consumption in rural areas provided a market for peasants to buy coal and fuel oil; the reconstruction of the power system greatly reduced the loss of using electricity and made it an energy of the highest increasing rate in rural areas. However, the popularization of household energy led to great surplus of straw and stalk, which was then burnt in fields, abandoned in rivers and caused new serious pollution [9]. At the same time, rural industrial consumption of energy increased rapidly, which contributed to great pollution and became a threat to the ecosystem in rural areas.

2.3. The sustainable development of rural energy and its challenge in China

Therefore, the sustainable development of rural energy is to satisfy the energy demand for the social and economic development, establish an efficient and economical energy demand and supply system and give priority to regenerate energy and maintain the improvement of environment in rural areas. And those are the four main features of SDRE.

According to the four characteristics, the main challenges SDRE facing in China are:

- Excessive consumption of biomass in districts of poor economy and bad environment has led to damage to vegetation, exacerbation of soil erosion, loss of organic matter in soil and deterioration of the ecosystem.
- The replacement of household energy consumption by commercial energy has caused surplus of biomass, which has led to damage to atmosphere, waters and soil.
- The small-scale, scattering energy consumption has caused low efficiency and high discharge.
- There are no such measures as smoke elimination, dusting and desulfuration in the energy using devices.
- We are short of support of technology and funds for energy regeneration and energy saving.
- We lack help in economic analysis and decision making.
- Rural areas lack environmental protection consciousness and measures, and the damage is more direct to nature.
- The environmental cost is external diseconomy.

3. The index system for appraising SDRE

According to the connotation of SDRE satisfying consumption demand, emphasizing energy saving and efficiency, giving priority to regenerate energy and improving environment and the main challenges facing SDRE in China, we must base our policy on the systematic, all-round, comparable, and operative principle, and try to use the common indexes that are easy to obtain in the country. In order to make the

indexes comparative, we must try to use relative indexes instead of absolute ones. We should set the 13 indexes of SDRE (Fig. 1) from four aspects, sustainable energy supply (B_1), sustainable energy utilization (B_2), sustainable energy exploitation (B_3) and sustainable zoology and environment (B_4).

The 13 indexes are followed: C_{11}, Energy satisfaction index for industry use: the percentage of industry energy supply over industry energy demand (%); C_{12}, Energy satisfaction index for household use: the percentage of household energy supply over household energy demand (%); C_{13}, Household electricity availability rate: the percentage of the number of the households where electricity is available over the overall number (%); C_{21}, Energy benefit index: GDP/energy consumption (RMB/kgce); C_{22}, Annual energy saving rate (%); C_{23}, Efficiency of energy used for cooking, water heating and pig-feed heating (%); C_{24}, The percentage of commercial energy in total energy used (%); C_{25}, Annual electricity consumption per capita (kWh); C_{31}, The percentage of biofuel utilization: the percentage of biofuel utilization refers to the ratio of actual exploitation quantity of biofuel against reasonable exploitation quantity of it (%). The ideal utilization rate is 1, $C_{31}<1$ when exploitation is not enough and $C_{31}>1$ when exploitation is overdone; C_{32}, The percentage of other renewable energy utilization: the percentage of other renewable energy (such as solar, wind, hydro energy) utilization refers to the ratio of actual exploitation quantity of other renewable energy against reasonable exploitation quantity of it (%). It is graded according to the exploitation level and the local resources; C_{41}, The reduced CO_2 discharging rate: the percentage of the reduced discharge of CO_2 over the total discharge, due to the use of energy saving and discharge reducing technology (%); C_{42}, The content of organic matters in the soil: organic matters content (g) per kilogram of soil (g/kg); C_{43}, The percentage of forest cover (%).

4. The determination of the weighing of the appraising indexes

The importance of each of the 13 appraising indexes on SDRE is different. To determine the weighing, this paper adopts Analytic Hierarchy Process (AHP) for

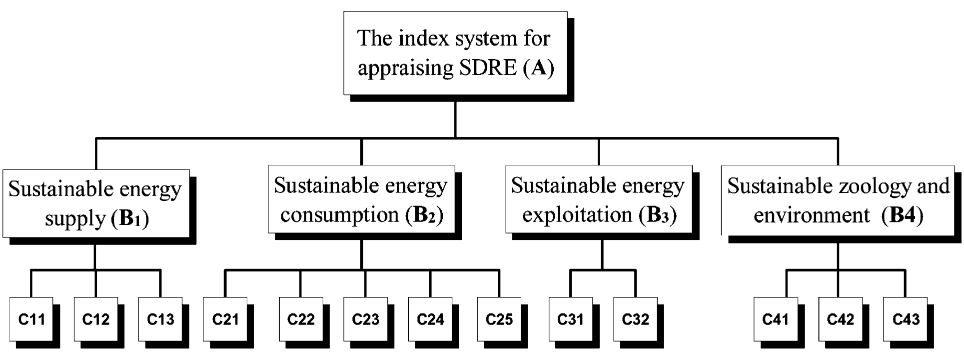


Fig. 1. Analytic hierarchy structure of the index system for appraising SDRE.

Table 1
B-level (to A) judgment matrix

A	B_1	B_2	B_3	B_4	W	λ_{max}=4.0511
B_1	1	1/5	1/3	1/4	0.072	*CI*=0.017
B_2	5	1	3	2	0.472	*RI*=0.90
B_3	3	1/3	1	1/2	0.170	*CR*=0.02
B_4	4	1/2	2	1	0.285	

Table 2
C-level (to B_1) judgment matrix

B_1	C_{11}	C_{12}	C_{13}	W	λ_{max}=3.0332
C_{11}	1	3	5	0.637	*CI*=0.0166
C_{12}	1/3	1	3	0.258	*RI*=0.58
C_{13}	1/5	1/3	1	0.105	*CR*=0.286

Table 3
C-level (to B_2) judgment matrix

B_2	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	W	λ_{max}=5.1230
C_{21}	1	3	5	4	3	0.484	*CI*=0.0308
C_{22}	1/3	1	3	2	2	0.226	*RI*=1.12
C_{23}	1/5	1/3	1	1/3	1/3	0.064	*CR*=0.0275
C_{24}	1/4	1/2	3	1	1	0.141	
C_{25}	1/3	1/2	3	1	1	0.149	

Table 4
C-level (to B_3) judgment matrix

B_3	C_{31}	C_{32}	W	λ_{max}=2
C_{31}	1	3	0.750	*CI*=0
C_{32}	1/3	1	0.250	*RI*=0.00
				CR=0

calculation [10]. AHP arrays the factors into several levels in decreasing order in terms of their subordinate relationship, establishes the relationship of the factors of different levels, compares the importance of the factors at the same level and then decides the order. After adopting many opinions from different sectors, the thesis brings forward B-level Judgment Matrix (Table 1) and C-level Judgment Matrix (Tables 2–5) according to the relationship between the upper level and the lower

Table 5
C-level (to B_4) judgment matrix

B_4	C_{41}	C_{42}	C_{43}	W	λ_{max}=3.0385
C_{41}	1	5	3	0.637	*CI*=0.0193
C_{42}	1/5	1	1/3	0.105	*RI*=0.58
C_{43}	1/3	3	1	0.258	*CR*=0.033

level in the Analytic Hierarchy Structure of the Index System for Appraising SDRE. Nine means extremely important and 1 means also important. The numbers from 1 to 9 and their reciprocals have the similar meaning.

By using approximate calculating methods, we work out the maximum feature value λ_{max} and the feature vector $\vec{W}$ of each judgment matrix and then carry out the consistency test of the judgment matrix. When $CR<0.1$, consistency of the matrix is satisfied; otherwise, we should adjust the judgment matrix.

The feature vectors of every judgment matrix show the general taxis of B level, i.e., the importance of all the factors of one level compared to the upper level can be showed in vector as:

$$W = (0.046, 0.019, 0.008, 0.215, 0.100, 0.028, \\ 0.062, 0.067, 0.128, 0.042, 0.186, 0.063, 0.036)$$

That is the weighing of the corresponding appraising indexes. According to the weighing, the first four indexes are energy benefit index (C_{21}), the reduced CO_2 discharging rate (C_{41}), the percentage of biofuel utilization (C_{31}) and annual energy saving rate (C_{22}).

5. The establishment of mathematical model for appraising SDRE

Suppose there are *n* appraising samples (*n* different districts in the same year, or *n* different years in the same district) $x_1, x_2, \ldots, x_n$, original matrix:

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \cdots \\ X_n \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1s} \\ x_{12} & x_{22} & & x_{2s} \\ \cdots & & & \\ x_{n1} & x_{n2} & & x_{ns} \end{bmatrix}, (s = 13)$$

Data standardized:

$$x^*_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, (i = 1,2,\ldots,n; j = 1,2,\ldots,13)$$

Thus,

$$X^* = \begin{bmatrix} x^*_{11} & x^*_{12} & \dots & x^*_{1s} \\ x^*_{21} & x^*_{22} & & x^*_{2s} \\ \dots & & & \\ x^*_{n1} & x^*_{n2} & & x^*_{ns} \end{bmatrix}$$

Considering weighing, the comprehensive appraising is $Z=X^{\cdot}\cdot W^{\mathrm{T}}$

Z refers to the appraising vector for SDRE and the value of each of its elements refers to the SDRE level of each sample; the higher the value is, the higher the level of SDRE. If appraising several years of some districts if the value is increasing as time goes by, then the development is sustainable; when different districts of the same time are appraised, the district of bigger value is more sustainable.

6. Applicable examples

Jinhu, Sheyang, Taixing, Suining, Wujin and Wuxian Counties are the rural energy comprehensive construction counties in Jiangsu Province of China in the Ninth Five-Year Plan. Comprehensive construction has promoted the sustainable development of rural areas. Table 6 shows the data of the index for appraising SDRE in the six counties in 2000.

Through calculation, Z^T=(0.19555, 0.15409, 0.17276, 0.13473, 0.19265, 0.21391). Therefore, the taxis of the six counties in accordance with their SDRE levels are Wuxian, Jinhu, Wujin, Taixing, Sheyang and Suining. By using the same method, we can work out the Z value of the SDRE of the six counties in 1995 and the speed of each county’s SDRE.

7. Conclusion

The sustainable development of rural energy (SDRE) is to satisfy the energy demand for social and economic development, establish an efficient and economical energy demand and supply system, give priority to regenerate energy and maintain the improvement of the environment in rural areas. According to the connotation of SDRE, the thesis set the 13 indexes for appraising SDRE from the four aspects of energy demand and supply, energy utilization, energy exploitation and environment. It uses analytic hierarchy process (AHP) to determine the weighing of each index. The weighing values of energy benefit index (C_{21}), the reduced CO_2 discharging rate (C_{41}), the percentage of biofuel utilization (C_{31}) and annual energy saving rate (C_{22}) are comparatively high, so they are the main factors that influence SDRE. In the end, the thesis sets the mathematic model and realizes the evaluation of the SDRE of different districts or of different years.

Table 6
The data of the index for appraising SDRE in six counties in 2000[a]

Counties	C_{11} (%)	C_{12} (%)	C_{13} (%)	C_{21} (RMB/kgce)	C_{22} (%)	C_{23} (%)	C_{24} (%)	C_{25} (kWh)	C_{31} (%)	C_{32} (%)	C_{41} (g/kg)	C_{42} (%)	C_{43} (%)
Jinhu	98	97	98	10.4	3.1	26.0	74.7	378.0	91	85	14	2.01	18.7
Sheyang	95	96	95	4.7	2.4	28.1	71.6	374.7	90	80	12	1.80	17.0
Taixing	100	98	100	9.0	2.1	35.5	71.3	487.1	91	78	11	1.20	16.5
Suining	95	90	95	2.4	2.8	25.4	82.7	263.5	93	75	10	0.78	23.2
Wujin	100	100	100	10.0	2.3	31.3	86.6	558.3	86	75	13	2.65	11.1
Wuxian	100	100	100	7.0	1.9	37.2	90.5	1644.7	90	80	13	2.40	11.2

[a] Source: Inspection and Acceptance Reports of the National Rural Energy Construction Project in the Six Counties of Jinhu, Sheyang, Taixing, Suining, Wujin and Wuxian in the Ninth Five-Year Plan, 2001.

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